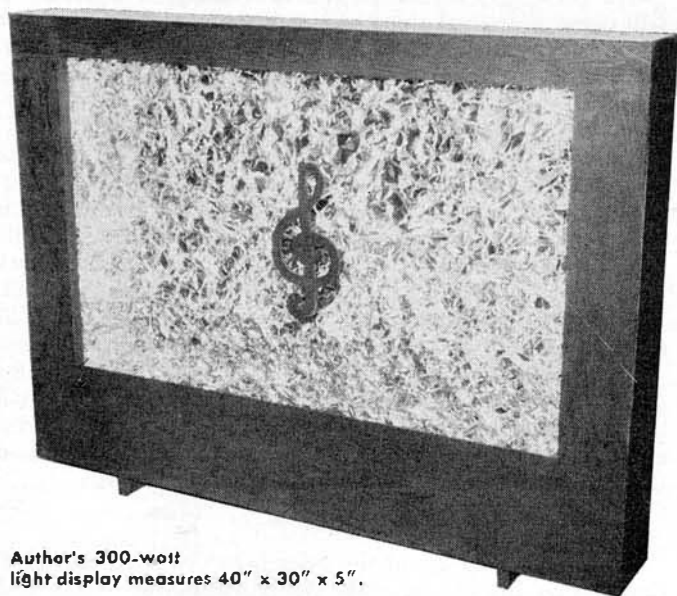


# SOLID-STATE 3-CHANNEL COLOR ORGAN

By DONALD LANCASTER

Construction of a well-designed display device that produces changes in the color intensity and hue in step with musical signals. Can be connected to hi-fi amplifier and will handle 1 kw. of light power.

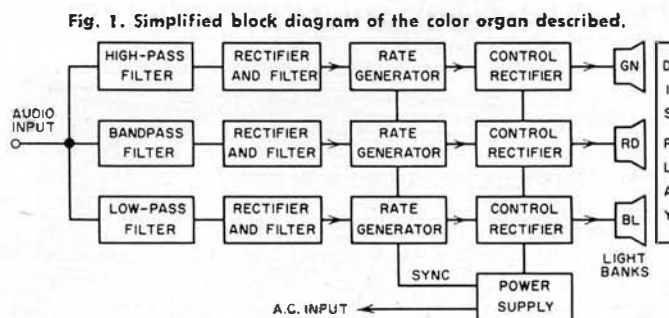


Author's 300-watt  
light display measures 40" x 30" x 5".

and a "too electronic looking design" have discouraged popular acceptance. It is felt that the present design overcomes some of these objections.

The color organ to be described consists of two units, a control box the size of several books, and its associated display, the size of a bookshelf. The former is capable of handling up to 360 watts per channel of regular 120-volt light bulbs, parallel connected, giving a total power capability of around one kilowatt. The control box operates off the loudspeaker terminals of any music system and consumes less than one watt of audio power. Efficiency is over 97% at full output, and control-box heating is negligible. Power "on-off," red drive, blue drive, and green drive are the only controls necessary. The over-all level is adjusted to meet average listening requirements by changing taps inside the unit; once set on a given music system, adjustment is unnecessary. The filters that separate the music into its components are adjustable to select the portions of the audio spectrum and to compensate for the nature and quality of the program material.

Fig. 1 is a block diagram of the system. It is first nec-



A COLOR organ may be broadly defined as any device that somehow relates a lighted display to an associated musical background. This is usually done in such a way that various colors correspond in some manner to certain frequencies in the musical selection.

A color organ typically consists of three filters separating the high-, mid-range-, and low-frequency component of the music, followed by circuitry allowing the control of the three primary light colors in a suitable display. In the past, color organs have been either too large or too small in scope or performance for average home hi-fi use; also, high cost

essary to divide the audio spectrum with the filter system. This is accomplished by a high-pass, bandpass, and low-pass filter network. Adjustable LC filters were chosen for their availability, their uniformity, and their steep slopes beyond cut-off.

Next, it is desirable to derive a d.c. control voltage from the filter output. A drive control at this point adjusts the maximum value of a given filter output. This is followed by a rectifier and filter network.

The actual illumination level is controlled by varying the duty cycle of the a.c. wave impressed on the load. This is shown in Fig. 2A. For convenience, alternate cycles are inverted by means of the full-wave rectifier to insure only positive or zero values of voltage. This does not affect load power.

A silicon-controlled rectifier (SCR) in series with each lamp load behaves as a simple switch, turning on when its gate is pulsed and remaining on for the rest of the cycle. The SCR turns off as its anode voltage approaches zero.

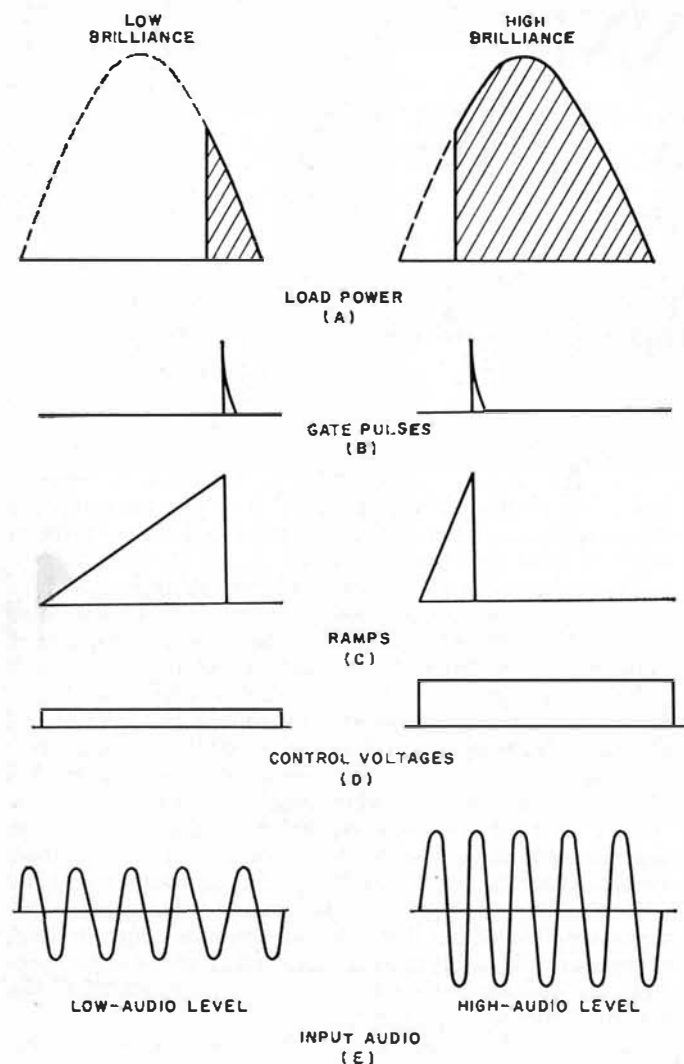


Fig. 2. Waveforms showing response of one channel to audio input.

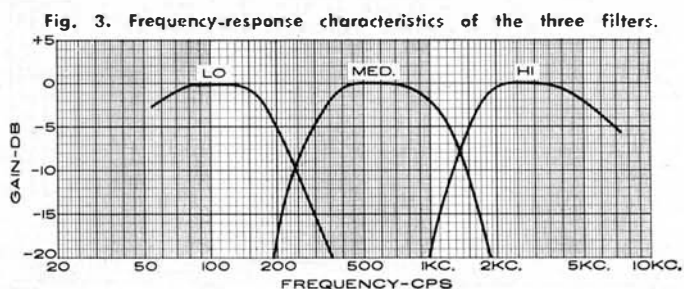


Fig. 3. Frequency-response characteristics of the three filters.



Control box (8" x 6" x 4") can handle 1 kw. of lighting power.

Figure 2B illustrates the gate pulses that are required.

The remaining block, as shown in Fig. 1, is the key to the control-box operation. This is the rate generator. This circuit converts the d.c. control signal from the filter to a time delay that determines when in the cycle the SCR will fire. Note that the greater the d.c. control signal, the *earlier* in the cycle the SCR will fire. This is accomplished by a saw-tooth oscillator, which always starts as the a.c. cycle passes through zero and stops, or discharges, after reaching a predetermined value. A gate control pulse is produced during the discharge. The input d.c. control signal determines the *slope* of the saw-tooth, and thus the time delay. A large d.c. control voltage will cause a steep slope and a very early discharge and SCR firing; a small signal will cause a gradual slope and a firing near the end of the cycle; while no signal at all will prevent the SCR from firing during that cycle. A synchronizing circuit always fires the rate generator during the zeroes of the a.c. voltage. This assures the same delay for a given control signal.

The SCR is also triggered at the a.c. zeroes, but will not remain on at this point. The net effect is to produce a negligibly small pulse of load power at this point—one that is not visible. Fig. 2C illustrates the ramps produced while Fig. 2D represents the control voltages, and Fig. 2E shows the original audio signals that produce the indicated result.

A detailed explanation of the rate generator and SCR theory is available elsewhere and will not be repeated here.

It should be noted that full-wave control of the light bulbs exists and, unlike some thyatron controls, the bulbs will light to full normal brilliance if enough audio signal is present. The forward drop of the SCR is considerably less and thus the SCR is more efficient than a gas thyatron.

### Circuitry

The circuit diagram of the color organ is given in Fig. 4. Considering the obvious first, S1 is the power switch and must be capable of handling full-load current. As d.c. bridge circuitry is employed, a fuse is a desirable and necessary item. This, too, is rated at maximum load current. PL1 serves as the indicator and receives its voltage through the reactive drop of C15. SR1, SR2, SR3, and SR4 are the inverting power diodes. These handle the total load current and must withstand the peak inverse of the applied line voltage. Zener diode CR4 and R1 serve the dual function of providing a stable voltage for the rate generators and also provide the synchronizing pulses required to fire the rate generators as the a.c. voltage swings through zero. R1 is a high-wattage unit that develops considerable heat and thus it should

be located well away from the rate-generator circuitry.

Having dispensed with the power-supply circuitry, the signal flow through the circuit may be traced. The signal enters *via* shielded cable to transformer T1. T1 serves two important purposes: First, it allows a suitable choice of drive signal and impedance matching and second, T1 isolates the bridge circuitry from the music system. Should any part of the circuit beyond T1 be grounded, the full line voltage will appear across CR4 causing the immediate and untimely death of this component, as well as possible other damage. Also note that a person coming in contact with this common may encounter *twice* the normal line voltage between this common and the nearest earth ground such as a radiator or water pipe. As long as the only case connection is made at J1 and as long as T1 remains in the circuit, there is no potential shock hazard.

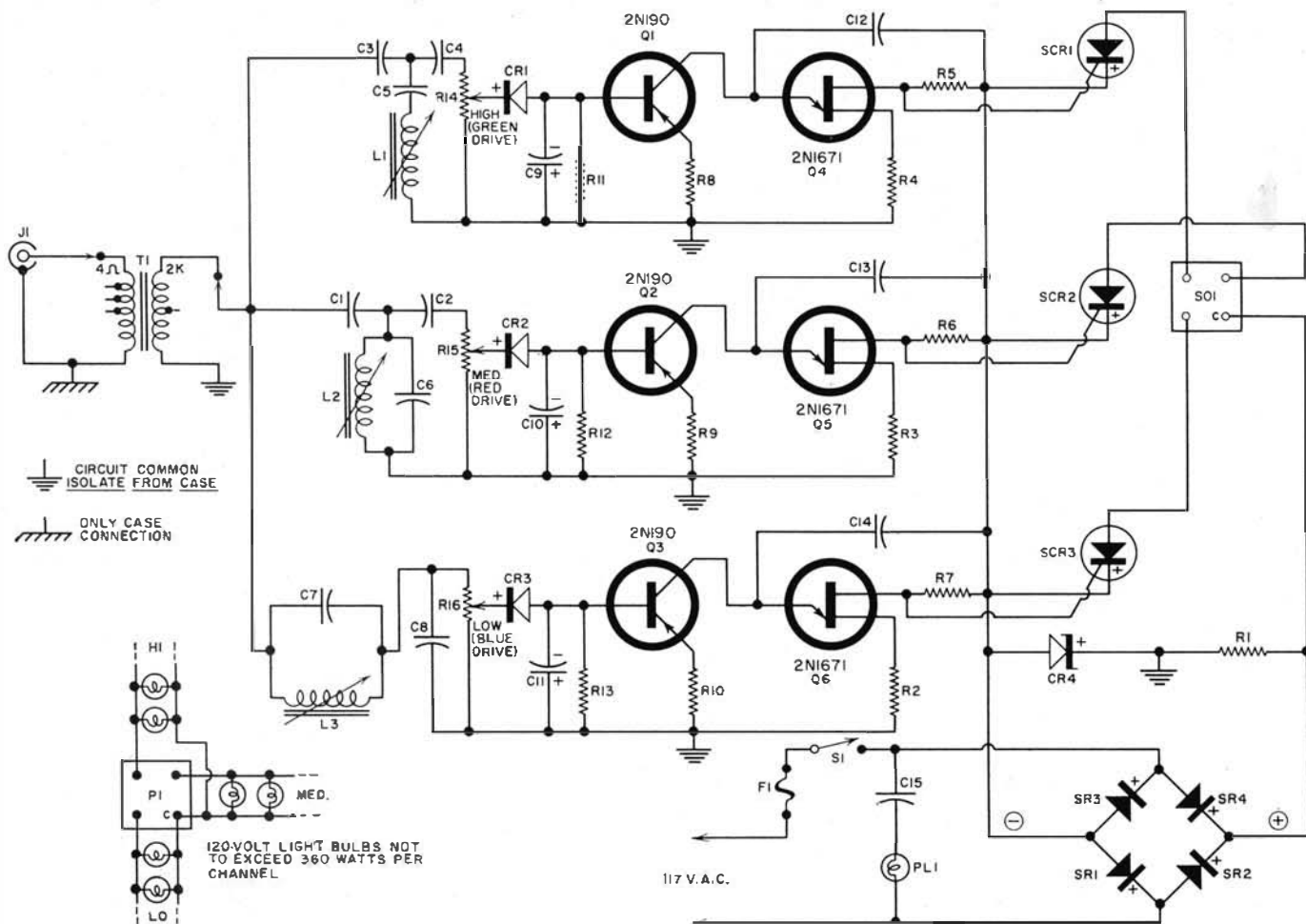
The signal splits beyond T1 and enters the filters. The filters are, respectively, an *m*-derived high-pass, a prototype bandpass, and an *m*-derived low-pass filter. The response curves are shown for typical inductor settings in Fig. 3. The steep slopes give brilliant crescendos of color as the

crossover point is reached in the music content. The inductors used employ variable ferrite cup cores which have the advantages of very small size, wide tunability, and negligible external field. Their disadvantages are very high cost and a lack of ready availability. A single cup core is capable of providing as much as 6 henrys  $\pm$  2 henrys inductance in a two cubic inch package. The cup core finds wide application in tone telemetry systems. Suitable substitutes are discussed later in this article.

Very little, if any, interaction was noted, so no isolating impedances are used between the filters. R14, R15, and R16 are the drive-control potentiometers and are 2-watt linear-taper controls. CR1, CR2, and CR3 rectify the separate channel audio signals. These signals are filtered by C9-R11, C10-R12, and C11-R13. These capacitors differ in value since more filtering is required in the lower frequency channels. Excessive filtering causes objectionable time lag effects, while insufficient filtering allows audio to foul up the rate generators.

Q1, Q2, and Q3 are the slope generators. They are *p-n-p* transistors. The apparent collector-emitter impedance is a

Fig. 4. Schematic of the color organ. Silicon-controlled rectifiers driven by unijunction transistors operate the light bulbs.

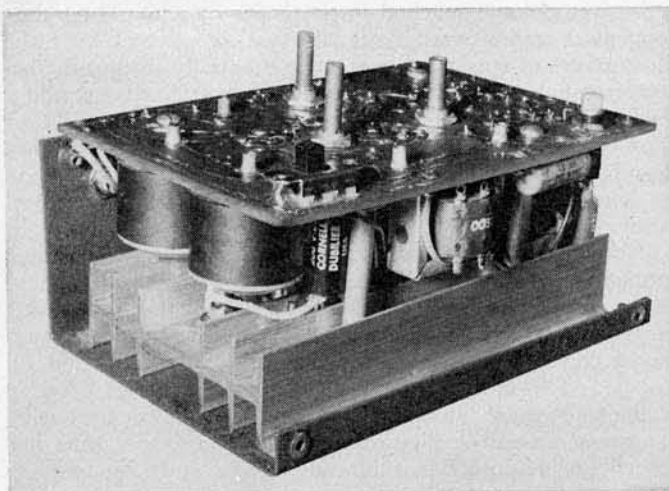


R1—3000 ohm, 10 w. wirewound res.  
R2, R3, R4—390 ohm, 1/2 w. res.  
R5, R6, R7—47 ohm, 1/2 w. res.  
R8, R9, R10—3300 ohm, 1/2 w. res.  
R11, R12, R13—4700 ohm, 1/2 w. res.  
R14, R15, R16—5000 ohm, 2 w. linear-taper pot  
C1, C2, C3, C4—1  $\mu$ f., 200 v. capacitor  
C5—0.02  $\mu$ f., 200 v. capacitor  
C6—15  $\mu$ f., 200 v. capacitor  
C7—0.015  $\mu$ f., 200 v. capacitor  
C8—1  $\mu$ f., 25 v. elec. capacitor  
C9—5  $\mu$ f., 25 v. elec. capacitor  
C10—10  $\mu$ f., 25 v. elec. capacitor  
C11—10  $\mu$ f., 25 v. elec. capacitor  
C12, C13, C14—0.33  $\mu$ f., 200 v. capacitor  
 $\pm$  10%  
C15—1  $\mu$ f., 200 v. paper or oil-filled capacitor

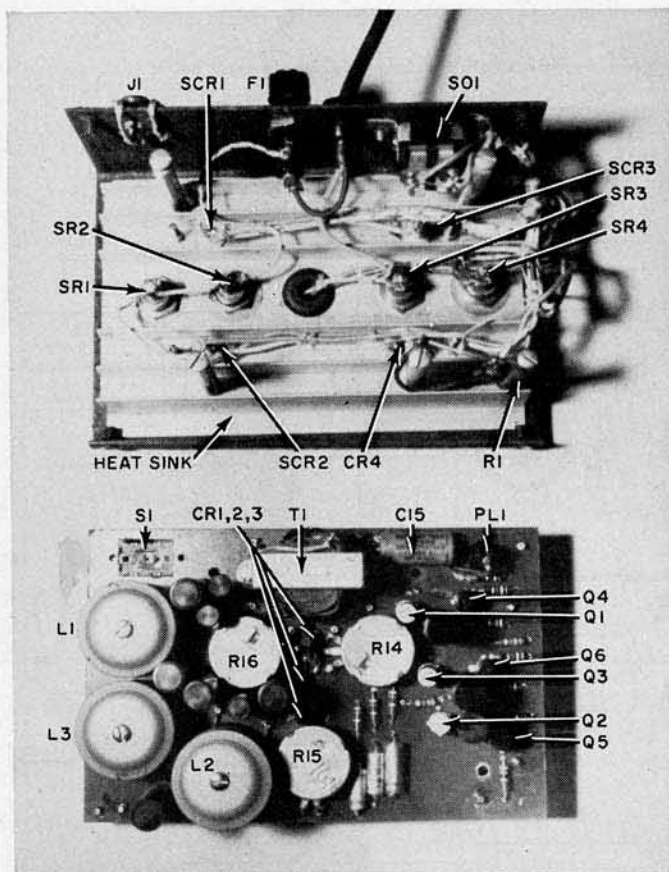
SCR1, SCR2, SCR3—1N250, 10 amp., 200 p.i.v. power diode  
CR1, CR2, CR3—1N34A, 100 ma., 50 v. diode  
CR4—1N1820, 20 v., 10 w. zener diode  
SCR1, SCR2, SCR3—Silicon-controlled rectifier (Texas Instruments Type T1-40A2, 200 v. p.i.v.)  
L1—25 hy. variable inductor (see text)  
L2—1.5 hy. variable inductor (see text)  
L3—4.5 hy. variable inductor (see text)  
T1—Universal audio output trans., 4-11,000 ohm pri. to 2.4A, 16 ohm sec. (see text)  
PL1—28 v., 40 ma. pilot light (Dialco)  
F1—3AG 8 amp fuse  
J1—Audio connector (coax.)  
S1—S.p.s.t. heavy-duty slide or toggle switch

SO1—Female connector (Janes S-404AB)  
P1—Matching plug (Jones)  
Q1, Q2, Q3—2N190 *p-n-p* transistor (or equiv.)  
Q4, Q5, Q6—2N1671 unijunction transistor  
Substitutes for cup-core filters:  
L1—UTC #VIC-8, Triad #C-17V, Stancor #C-2317  
L2—UTC #VIC-12, Stancor #C2327, Thordarson #26C40, Triad #C-21V  
L3—UTC #VIC-14, Triad #C-6X, Thordarson #26C42, Stancor #C-1706  
The UTC units are tunable toroids and are higher in cost than fixed values. All other are non-variable fixed inductors. Filter values might require alteration.





Control box of the color organ shown here with cover removed.



Heat sink and chassis-mounted components are shown at the top. At the bottom is the circuit board and associated components.

function of the base drive current. This variable impedance serves as a variable resistance, which, respectively, charges timing capacitors C12, C13, or C14. These capacitors are discharged after reaching a critical value by unijunction transistors (UJT) Q4, Q5, and Q6. A pulse is produced across R4, R3, or R2 as the respective UJT fires. This is the gate-control pulse. R8, R9, and R10 serve as current-limiting resistors, while R5, R6, and R7 act as the respective UJT load resistances. It may be noted that the circuitry from the d.c. filters onward is simply in triplicate.

The heart of the unit is the three silicon-controlled rectifiers SCR1, SCR2, and SCR3, rated to handle maximum channel load current and peak forward line voltage. The units chosen, the Texas Instruments Type TI-40A2, represent a good compromise in performance, economy, and availability. SO1 is the output jack which should be female for safety

reasons. It should be capable of handling total display current.

The display circuitry is straightforward, consisting of three strings of lamp sockets sharing a common connection. Heavy cable should be used between control box and display since up to 9 amperes of current may be handled.

### Display Considerations

The display, as chosen, is intended for home hi-fi use or as a frontispiece for a small band. Its size and configuration are primarily determined by the materials available and the over-all effect desired. The unit measures 40" x 30" x 5", not including the small feet, and is constructed of 3/16" plywood, using glue and small wood screws. The reflective liner is simply heavy-duty aluminum foil (freezer foil) crumpled and stapled in position to the back panel of the display. The display unit is finished flat black. A white Formica top adds a professional touch and saves some surface finishing. The treble clef is merely ornamental and is supported by two long 8-32 machine screws. The display has a dozen cleat sockets in the bottom for the light bulbs. These are wired as follows: low (blue), low (blue), low (blue), med. (red), low (blue), med. (red), med. (red), hi (green), med. (red), hi (green), hi (green), hi (green). This was found to give a uniform spectrum of color and avoids sharp discontinuities between color channels. Regular 25-watt, 120-volt colored light bulbs are used. Note that four lamp bulbs are used for each of the three channels and they would consume 100 watts of power per channel with the lamps fully lighted. In operation about 70 watts is used per channel. As the circuit stands, as many as fourteen 25-watt bulbs could be handled in each of the three channels, if considerably more light is desired.

Additional lights across the top of the display would balance the final appearance, but this is hardly necessary. The display is quite visible even under high room illumination. The best over-all color effect is obtained in a subdued lighting area. The control box is capable of driving three or four displays simultaneously, or a single large display.

### Packaging

The control box is a spot-welded steel box with a brushed aluminum top plate and is finished in heavy gray wrinkle. The electronic components fall naturally into three groups.

The first group is the chassis-mounted parts, which consist of the input and output connectors, the line cord, and the fuse. The second group consists of all high-current devices, which mount on a piece of extruded heat sink, using insulated mounting techniques. The power diodes, R1, the zener synchronizing diode, and the three silicon-controlled rectifiers mount on this sink. In continuous operation, a slight temperature rise of the sink will be noted, but hardly enough to justify venting the control box.

A printed wiring board mounts the third group of components, consisting of the cup cores, the rate generators, all small parts, the switch, and the pilot light. Interconnections are made by way of solder terminals and small wire jumpers. Spacers separate the circuit board and the heat sink. A 1/8" circuit board was used, single copper clad.

Four rubber feet and three Raytheon color-cap knobs complete the package; the knob colors correspond to the channel colors and are in the relative position as the channels appear in the display. The top plate is 1/32" aluminum, wire brushed and anodized with lye. Decals and a plastic spray coat complete the construction of this panel.

### Home Construction

The shop methods and production techniques used in the construction of this unit are merely for convenience and, by making several obvious changes, the unit may be easily duplicated by the home constructor.

The use of a larger box and wired circuitry is recommended. (Continued on page 76)

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## Solid-State Color Organ

(Continued from page 58)

mended, employing a "Minibox" or equivalent. A block of aluminum or copper of fairly good size can replace the heat sink extrusion. The insulated mounting wafers and bushings provided with the zener, the power diodes, and the controlled rectifiers must be used and all circuitry must be isolated from the heat sink. The substitution of standard 6-32 hardware for the "Rivnuts" used is obvious.

The cup cores were custom-wound for this application and neither the cups nor their contained heat-formed coils are readily available. However, small filter chokes or filter reactors of similar inductance values are readily available at parts stores. Typical substitutes and their values are given in the parts list accompanying Fig. 4.

Liberal use of tie-points and possibly a component board or two should make wiring straightforward.

The power diodes may be purchased as surplus items, for a considerable cost savings can be realized on this item alone.

Component arrangement is not at all critical as long as all leads remain sensibly short. The power resistor R1 should be spaced well away from the transistors. Heavy-gauge wire should be used for the higher current portions of the circuit. Be certain not to omit T1 and be certain that the common bus does not contact either the case or external ground; failure to do so will give the zener diode a life measured only in milliseconds.

Crossover frequencies of 250 and 1400 cps perform reasonably well for all applications and represent the median values of possible crossover points.

"Tuning up" consists simply of attaching the unit to the 8- or 16-ohm loudspeaker terminals of the hi-fi sound system and adjusting the input taps on T1 to give optimum performance. Moderate loading of the speaker may occur, dropping the volume level considerably in some cases, depending on the output impedance and power rating of the amplifier. Turning up the volume or loudness control on the unit will compensate for this effect.

### Performance

Performance is surprisingly good and is singularly beautiful at moderate listening levels. Unlike other color-organ designs, the lights completely extinguish between passages, giving a weird and beautiful effect. The unit may be used with any audio equipment, but the use of a.c.-d.c. equipment is not recommended.

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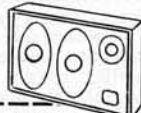
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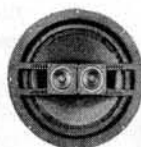
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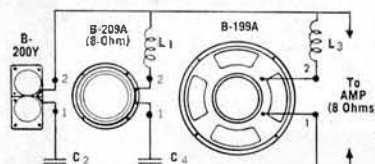


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or, more practically, (2) add a "phantom" center output transformer and use this to drive the display.

No definite estimate of bulb life can be given since in over three months of continuous demonstration and use not one bulb has failed. Apparently, bulbs will last as long or possibly longer than they would under normal use.

Additional audio gain could be incorporated in the control box to allow operation from a microphone, but experiments showed that ambient noise levels, i.e., conversation and traffic, posed quite a severe problem to this type of operation.

In use with a small band, the control box can be attached to the guitar or accordion amplifier.

Speech fed into the color organ can cause objectionable transients and, in some cases, it is advantageous to mute the organ during this type of program material.

It is felt that the present design is somewhat more desirable and practical than thyatron or vacuum-tube-controlled devices, giving more light and better performance in a somewhat smaller and more usable package. ▲

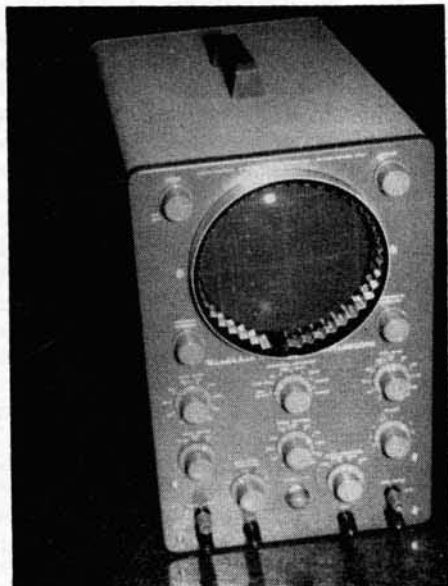
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By CLARENCE A. ELLIOTT

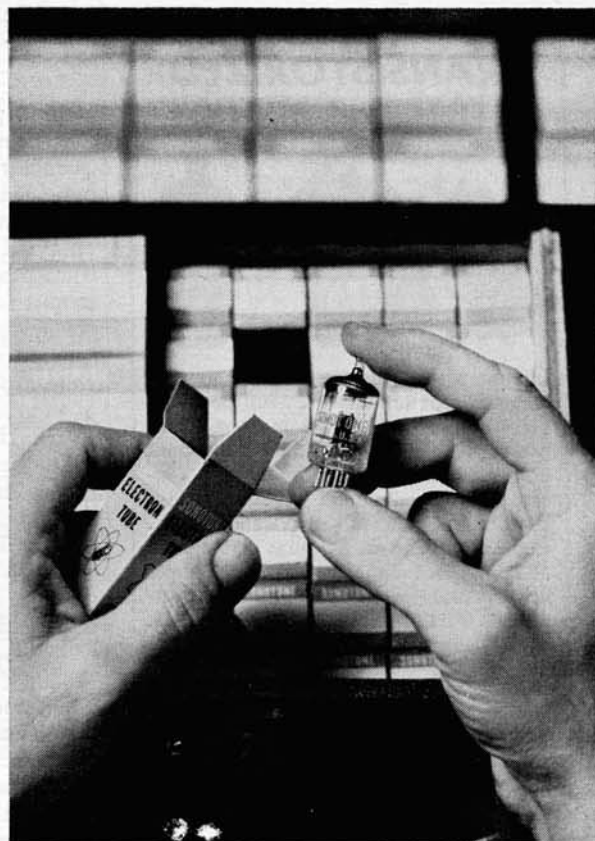
**I**F you own one of the earlier Heathkit oscilloscopes, you may be having trouble with the graticule. It may be either so tight that it buckles when in place or so loose that it falls out of the CRT shield. This difficulty can be easily overcome.

First, cut out a strip of aluminum or other sheet metal about  $\frac{3}{8}$  inch wide and 20 inches long. Next crimp the strip back and forth with a pair of pliers. If desired you can now paint it with flat black paint to reduce light glare.

Now trim the graticule, if necessary, so it fits loosely and set it in place. Bend the strip into a circle and place it in front of the graticule as shown in the photo below. The graticule can now be rotated for adjustment but is held firmly in place for use. ▲



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